

THE VASCULAR FLORA OF THREE ABANDONED RICE FIELDS, GEORGETOWN, SOUTH CAROLINA: A 39 YEAR COMPARISON

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ABSTRACT

The vascular plant species at three abandoned rice fields, Alderly, Airport, and Thousand Acre Rice Field at the Belle W. Baruch Institute for Marine Biology and Coastal Research, Georgetown, South Carolina were sampled and compared over a 39 year period, 1967–2006. One hundred twenty-four species in 91 genera and 44 families were identified at the three marshes, including eight non-native species. The Institute experienced a category 4 hurricane, Hurricane Hugo, on September 22, 1989. The number of vascular plant species decreased at the two least saline marshes, by 32% at Alderly and by 30% at Airport, immediately after Hugo. The number of species at Alderly increased when surveyed in 2002–2006, while there was no change in the number of species at the Airport marsh since Hugo. There was little change in the number of species at Thousand Acre Rice Field, the most saline marsh, during the 39 year study. *Phragmites* has recently invaded Airport Marsh and Alderly and may out compete and exclude native vascular plant species in the future.

KEY WORDS: vascular flora, South Carolina, abandoned rice fields, brackish marshes, Hurricane Hugo

RESUMEN

Se muestrearon y compararon durante un periodo de 39 años, 1967–2006, las plantas vasculares de tres campos de arroz abandonados, Alderly, Airport, y Thousand Acre Rice Field en el Belle W. Baruch Instituto de Biología Marina e Investigación Costera, Georgetown, Carolina del Sur. Se identificaron ciento veinticuatro especies de 91 géneros y 44 familias en los tres lugares, incluyendo ocho especies no nativas. El Instituto sufrió un huracán de categoría 4, Huracán Hugo, el 22 de septiembre de 1989. El número de plantas vasculares decreció en las dos últimas lagunas salinas, en un 32% en Alderly y en el 30% en Airport, inmediatamente después del Hugo. El número de especies en Alderly aumentó cuando fue revisado en 2002–2006, mientras que no hubo cambio en el número de especies en la laguna de Airport desde el Hugo. Hubo pocos cambios en el número de especies en Thousand Acre Rice Field, la laguna más salina durante los 39 años de estudio. *Phragmites* ha invadido recientemente Airport Marsh y Alderly y puede que comita y excluya especies vasculares nativas en el futuro.

INTRODUCTION

The objective of the present study was to compile a vascular flora of three abandoned rice fields and to describe changes in the flora of the three brackish marshes in which they exist, on the Belle W. Baruch Institute for Marine Biology and Coastal Research Georgetown, South Carolina, over a 39 year period, 1967–1971, 1987–1991 and 2002–2006. The marshes, Alderly, Airport, and the 1000 Acre Rice Field, were selected in 1967 by John Baden for a masters degree project when he was a graduate student at the University of South Carolina (Baden 1971). Airport marsh, 62.9 hectares, 33.3467 N, 79.2488 W, was the smallest study site. Alderly, 33.3544 N, 79.2439 W and the 1000 Acre Rice Field, 33.3029 N, 79.2514 W, are 173.3 and 248.6 hectares, respectively (Fig. 1).

The vascular flora of these marshes was first catalogued by Barry (1968) in relation to soil types during the growing season of 1967–1968. The brackish marsh soils are acid, continually saturated, and very poorly drained. Baden (1971) examined the effect of tidal flooding, salinity, pH, soil texture and organic content on the composition of vascular plants in these three brackish marshes. Baden et al. (1975) found that salinity, pH, texture, and organic matter were not important edaphic factors influencing the zonation of vegetation in Alderly and the Airport Marshes.

Stalter and Baden (1994) compared the vascular flora of Airport, Alderly, and Thousand Acre Rice Field in 1987–91 with the vascular flora at the same three marshes in 1967–68, concluding that there was little change during the 20 year interval. The Jaccard indices of similarity were high (> 0.8) in pairwise comparisons

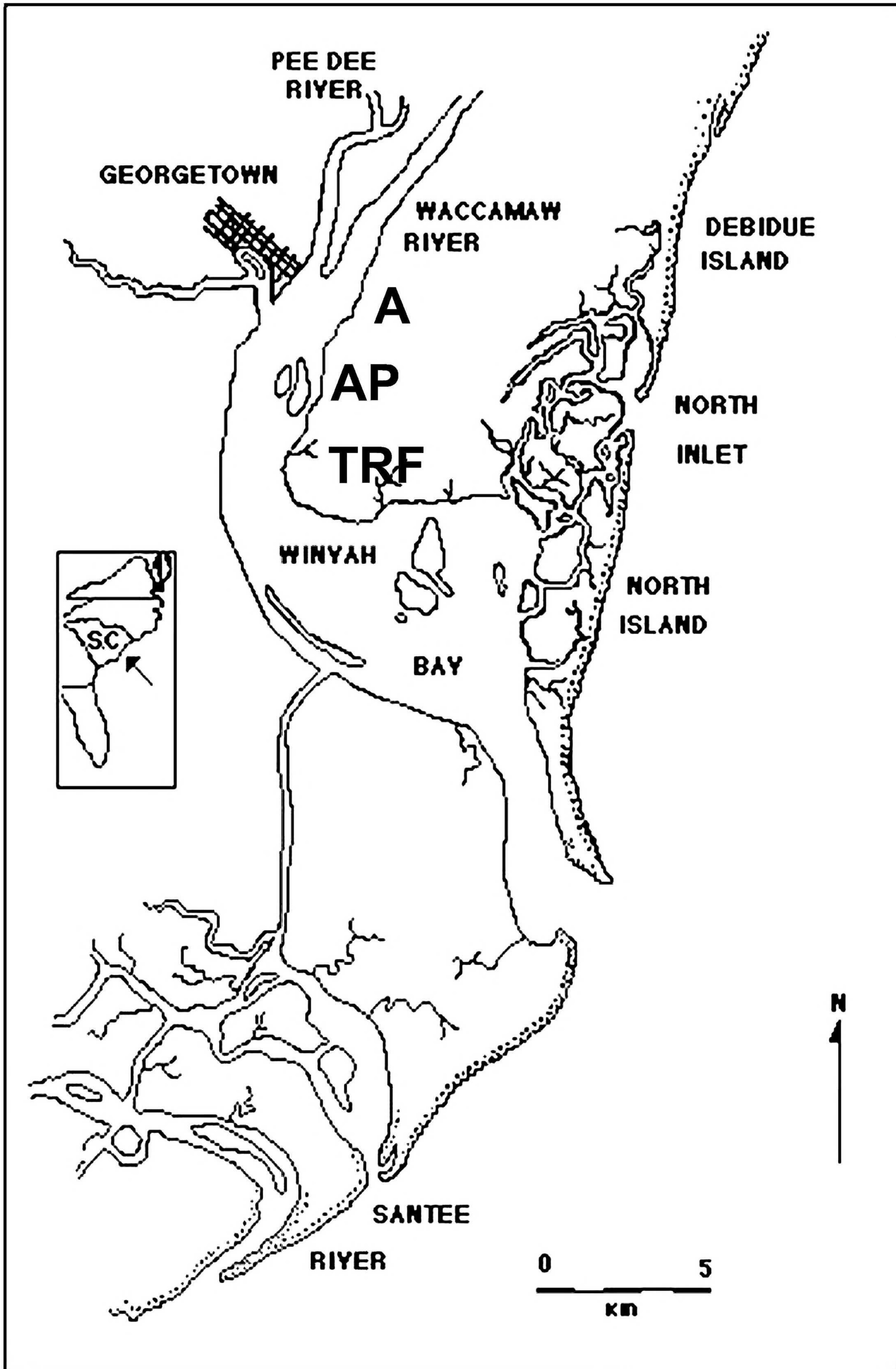


FIG. 1. Location of three study sites, Alderly (A), Airport (AP), and Thousand Acre Rice Field (TRF) at the Baruch Institute, South Carolina.

of vascular plant species among marshes from 1967–68 to 1987–91. Of the species observed in 1968 and 1991, 91% were native to the United States. By comparison, native vascular plant species comprised 72.5% of the flora at Fort Sumter, South Carolina (Stalter & Lamont 1993); 65.6% of the flora at Cape May Point State Park, New Jersey (Sutton et al. 1990) and 76.3% of the flora at Assateague Island, Virginia (Stalter & Lamont 1990).

Stalter (1973) studied the factors influencing the distribution of vascular plant species in the Cooper River estuary, South Carolina, in July 1971. The marsh vegetation was sampled by transects at 23 sites from Sullivan Island at the mouth of the Cooper River to freshwater marshes well inland. The transects were laid out perpendicular to the Cooper River and marked at the elevated end by a concrete post or, if available, by a Coast and Geodetic Survey bench mark. Forty nine vascular plant species were identified in Stalter's (1973) study. Zonation of vegetation was pronounced in salt marshes. *Spartina alterniflora* was the most flood tolerant taxon and occupied the widest range in elevation. Zonation of vascular plant species in the brackish marshes (salinity 1.0 ppt to 15 ppt) was less pronounced than in the salt marshes. *Spartina cynosuroides*, *Juncus roemerianus* and *Scirpus validus* occupied the most flood prone zone of the brackish marshes. Freshwater marshes (those with salinity values less than 1.0 ppt) were populated by *Alternanthera philoxeroides*, *Ludwigia* spp., *Pontederia cordata*, *Saururus cernuus* and *Zizaniopsis miliacea*. All of the aforementioned species at Cooper River were present in the abandoned rice field marshes at Baruch.

Eleuterius (1972) described the marshes of Mississippi based on extensive field work in 1968 and 1969. Vegetation was sampled by line transects and list-count quadrats at 19 stations in all the estuarine marshes of Mississippi. He reported over 300 species of vascular plants in Mississippi marshes; no species list was published (Eleuterius 1972). He reported that there was a greater diversity of vascular plant species in freshwater marshes than in brackish or salt marshes; these results are similar to those in the abandoned rice fields of the Baruch Institute. Distribution of species at the Baruch brackish marshes was also similar to that reported by Stalter (1973) at the Cooper River. Eleuterius also noted the effect of salt water on vegetation during a growing season. *Crinum americanum* and *Iris virginica*, were present in brackish marshes in April when water salinity value were low. By June, these same species, "were dead or disappeared." *Crinum* and *Iris virginica* were growing vigorously and producing flowers in freshwater marshes.

Stalter (1972) conducted a survey of the summer and fall flora at Brookgreen Gardens from July to December 1970. He reported 639 species of vascular plants though he did not describe the plant communities at Brookgreen. Many of the taxa reported by Stalter (1972) at the brackish marshes at Brookgreen, notably *Juncus* and *Spartina*, were also present in brackish marshes at the Baruch Institute.

Stalter (1971) reported the summer and fall flora of Huntington Beach State Park, Georgetown County, South Carolina. Included in the 321 taxa were 66 wetland species, though not all of these species were found at the abandoned rice fields at the Baruch Institute. Common to both sites are species of *Carex*, *Eupatorium*, *Hydrocotyle*, *Juncus*, *Rhynchospora*, *Sagittaria*, *Spartina*, *Taxodium*, and *Typha*.

A study at the Yawkey Center, a site adjacent to the Baruch Institute, was conducted by Nelson from early spring 1990 to September 1992. Ten plant communities were described by Nelson, in an unpublished inhouse document. One of his communities was old rice fields. Nelson stated that these sites, depending on flood history and salinity may be highly complex and botanically diverse. Nelson cites 21 taxa specifically found in the abandoned rice fields. Most of these taxa were also identified at the abandoned rice fields at the Baruch Institute.

History

The marshes in the study are located on Waccamaw Neck, bordering Winyah Bay (Fig. 1). In 1718, George II granted Lord Carteret 7500 hectares that composed the original Hobcaw Barony. Carteret sold his land to a land speculator, John Roberts in 1735, who subdivided the property and sold it to developers. Ultimately, the area was settled and the tidal wetlands bordering the Waccamaw River were diked and drained for rice production. By the beginning of the Civil War (1861), 13 major rice plantations at Hobcaw were producing approximately a half a million pounds of rice annually (Porcher 1976).

At the end of the Civil War (1865), plantation owners lost their slaves who provided the labor that sustained the rice industry (Porcher 1976). The few rice growing plantations that survived were devastated by a series of hurricanes in the 1890s and early 1900s (Baden 1971). The most severe hurricane, the storm of 1893, rivaled Hurricane Hugo (1989) in intensity and destruction. The devastating hurricane of 1893 plus additional hurricanes and competition from rice growers in the Gulf States terminated the rice industry in South Carolina by the early 20th century.

Many took advantage of the demise of the coastal plantation system. South Carolinian Bernard Baruch purchased 7,500 hectares along Waccamaw Neck between 1905 and 1907, as a hunting preserve. Baruch (1957), claimed the salt marshes (at Hobcaw Barony), "once offered the finest duck hunting in the United States."

After his daughter's demise, Bernard Baruch established the Belle Baruch foundation in his daughter's honor as a natural laboratory for research and teaching. Today, two research institutes, one dealing with marine science and affiliated with the University of South Carolina and the other with forestry and affiliated with Clemson University, pursue scientific studies in the forest and marshes at Hobcaw and in the Atlantic Ocean. The foundation was selected by NSF in the mid 1980s as a Long Term Ecological Research Site.

Climate

Coastal South Carolina has a subtropical climate. Average rainfall at Georgetown is 1,368 mm. August is the wettest month averaging 180 mm while November is the driest month averaging 75.4 mm. Snowfall is rare; 10 mm falls in an average year. July is the warmest month with an average temperature of 27.1 C. January, the coldest month, has an average temperature of 8.7 C. The growing season averages 254 days (Anonymous 1996).

Soils

Soils at Alderly are Levy silty clay loams. Levy soils are, "fine mixed superactive acid (pH 5.0–5.5) thermic Typic Hydraquents. Organic content of the soils at Alderly ranged from 24–30% (Baden 1971). The average mineral component at Alderly was sand (25%) silt (51.5%) and clay (23.5%). Table 3 reports the soil data of Baden (1971).

Soils at the more saline Airport and 1000 Acre Rice Field are included in the Bohicket Series. These soils are very poorly drained, very permeable soils that formed in marine sediments in tidal marshes. The taxonomic class: Fine mixed Typic Sulfaquents. Soils at Airport and Thousand Acre Rice Field are acid in reaction at the two sites with pH ranging from 5.0 to 6.0 and 5.0 to 5.5 at the two respective sites. The organic content of soils at Airport marsh ranged from 25–28%; organic content of soils at Thousand Acre Rice Field from 19–33%. Silt was the dominant soil fraction at both sites. Soil fractions at Airport were sand (18%), silt (57.5%) and clay (24.5%). At the Thousand Acre Rice Field the fractions were 24% sand, 41.2% silt and 34.8% clay (Table 3).

Elevation measurements within the marshes were made using a surveyors transit and stadia pole. Transit measurements indicated that there was little difference in elevation across the abandoned rice fields (Baden 1971).

Hurricane Hugo

Hurricanes have struck the South Carolina coast an average of once every 2.5 years in the 20th century (Gentry 1971). The most notable during the course of this study was Hurricane Hugo in 1989 (Gardner et al. 1991), which was a "storm of the century" hurricane, causing catastrophic damage to upland forests at the Baruch Institute (Blood et al. 1991; Gardner et al. 1991). Sustained winds of 122 km/h with gusts as high as 150 km/hr were recorded in Charleston, 75 km south. Winds at Georgetown peaked at 112 km/hr. Many trees were toppled and/or broken (Stalter & Baden 1994). Hugo's storm surge in the Thousand Acre Rice Field, Airport and Alderly marshes was approximately four meters, depositing debris up to 0.5 meters at the Thousand Acre and Airport marshes (Stalter and Baden 1994). The resulting raft of vegetation was colonized by vascular plant species not normally associated with brackish marshes (Stalter and Baden 1994). These

were *Cakile edentula*, a dune species; *Erectites hieracifolia*, a disturbed site invader; *Eupatorium capillifolium* and *Glottidium vesicarum*, a disturbed field associate; *Panicum amarum*, an upper, rarely flooded salt marsh fringe associate; *Pinus taeda*, an upland species; *Triadica sebifera*, an Asiatic tree that invades disturbed sites; *Solidago sempervirens*, an occupant of coastal dunes and the upper, rarely flooded salt marsh fringe; and *Strophostyles helvola*, a coastal dune associate (Stalter and Baden 1994). Thirteen years later, by 2002, the raft of “wrack” had decomposed or washed away along with the aforementioned ephemeral vascular plants.

METHODS

The vegetation in three brackish marshes, Thousand Acre Rice Field, Airport and Alderly was sampled at least once a month during the growing seasons beginning July 2002 and terminating in May 2006. The flora was compared with the vascular flora reported by Baden et al. (1975) during the collecting seasons of 1968–69 and Stalter and Baden (1994) during the growing seasons of 1987–91 (Appendix). Voucher specimens collected in 1968–69, 1987–91 and 2002–06 were deposited in the herbarium at the University of South Carolina, with the exception of taxa mailed to experts for verification. Accession numbers will be assigned to the voucher specimens by Dr. John Nelson, Batson Herbarium, University of South Carolina.

The Appendix contains an inventory of the vascular plant species reported in 1968–69 by Baden et al. (1975), the growing season of 1987–91 by Stalter and Baden (1994) and the present study 2002–06. Only species that reproduce and persist longer than a single growing season without cultivation are tabulated in Table 1. Non-native species are designated by an asterisk; non-native status follows Gleason and Cronquist (1991) and Wunderlin (1998). Nomenclature presented in this flora agrees with Kartesz (1994). When differences in nomenclature occur, the older name, listed in Radford et al. (1968) is listed as a synonym and enclosed in brackets. The families, genera and species in the Appendix are listed alphabetically.

Salinity data presented by Baden et al. (1975) were combined with that recorded by Dr. Dennis Allen, Director, Baruch Institute (2002 pers. comm.) and Conner and Inabinette (2005) over a twenty year period (Table 2).

Pairwise among the three sites, floristic similarity was measured by Jaccard coefficients (Kaufman and Rousseeum 1990, Jaccard 1908), calculated from 2×2 contingency tables, and tested for significance by approximate randomization (Noreen 1989). Each coefficient (test statistic) was compared to its sampling distribution under the null hypothesis (H_0) of a random distribution of taxa across the three study sites. These sampling distributions were achieved after 99,999 randomizations of the species labels in the JMP (SAS) row-by-column data, with the observed data also considered as a randomization under H_0 . P-values were calculated in standard fashion as $P = (NGE + 1) / (NS + 1)$ where NGE is the number of null coefficients in the sampling distribution that were greater than or equal to the test statistic and with NS as the number of randomizations performed (Manly 1997). For reference in Table 4, the mean of the null distribution is given for each observed Jaccard coefficient.

RESULTS AND DISCUSSION

The vascular flora at the three brackish marshes of the Baruch Institute includes 124 species in 91 genera within 44 families. Dicots (64 species) are more numerous than monocots (55 species) (Table 1). Eight species, *Alternanthera philoxeroides*, *Arundo donax*, *Chenopodium album*, *Echinochloa crus-galli*, *Murdania keisak*, *Phragmites australis*, *Triadica sebifera* and *Verbena brasiliensis* are non-native (Appendix). Seventy-one species occurred exclusively at only one site, while only 26 species occurred at all three sites. Alderly, the least saline marsh, contained the greatest number of species (110). Wass and Wright (1969) working in coastal wetlands of Virginia, reported a greater species diversity in fresh water marshes than in salt water marshes. Airport and Thousand Acre Rice Field had 54 and 39 species, respectively. *Cyperus drummondii* collected at Alderly was the rarest species identified in this study. It has been collected only once before in South Carolina, in the 1940s (Nelson, Director, Batson Herbarium, USC, 2003 pers. comm.). This is the first South Carolina record of this taxon in nearly 60 years.

Feral pigs are a major source of soil disturbance at all marsh sites, especially at the intertidal zone and

TABLE 1. Summary of the vascular flora at three brackish marshes, Georgetown, South Carolina.

| | Ferns | Conifers | Dicots | Monocots | Total |
|--------------------|-------|----------|--------|----------|-------|
| Families | 3 | 1 | 30 | 10 | 44 |
| Genera | 3 | 1 | 55 | 32 | 91 |
| Species | 4 | 1 | 64 | 55 | 124 |
| Native Species | 4 | 1 | 60 | 51 | 116 |
| Introduced species | 0 | 0 | 4 | 4 | 8 |

TABLE 2. Water salinity at three brackish marsh sites. Data from Baden 1975, Stalter and Baden (1994), and Conner and Innabnette (2005). Values at all sites were greater than 20 ppt during the Hurricane Hugo storm surge.

| Study site | Salinity, (ppt) |
|--------------------------|-----------------|
| Thousand Acre Rice Field | 0–23 |
| Airport marsh | 0–16 |
| Alderly | 0–18.5 |

TABLE 3. Organic content and soil fraction (%) at three abandoned rice fields. Data from Baden (1971).

| Study Site | Range of Organic Content (%) | % of Soil Fractions | | |
|--------------------------|------------------------------|---------------------|------|------|
| | | Sand | Silt | Clay |
| Thousand Acre Rice Field | 19–33 | 24.0 | 41.2 | 34.8 |
| Airport | 25–28 | 18.0 | 57.5 | 24.5 |
| Alderly | 24–30 | 25.0 | 51.5 | 23.5 |

TABLE 4. Species similarity measured by Jaccard coefficients among three sites. Statistical significance determined by approximate randomization tests involving 99,999 randomizations of the species label in the row-by-column JMP (SAS) data file. The null, mean Jaccard coefficients are from the sampling distribution of the Jaccard achieved after the randomizations.

| Site comparison | Jaccard coefficient | Null mean | P-value | Species in common/total |
|--------------------------------------|---------------------|-----------|---------|-------------------------|
| Thousand Acre Rice Field vs. Airport | 0.388 | 0.124 | 0.00001 | 26/67 |
| Thousand Acre Rice Field vs. Alderly | 0.263 | 0.157 | 0.00019 | 31/118 |
| Airport vs. Alderly | 0.414 | 0.197 | 0.00001 | 48/116 |

upland border. Disturbance may enhance species diversity at the three marshes since disturbed areas may be colonized by *Chamaecrista* (*Cassia*) and *Chenopodium album* as well as by true brackish marsh species, e.g., *Pluchea camphorata* and *P. foetida*.

Ten woody species are reported at Alderly for the first time: *Ilex cassine* var. *cassine*, *Ilex opaca*, *Itea virginica*, *Nyssa sylvatica* var. *biflora*, *Rosa laevigata*, *Rosa palustris*, *Salix caroliniana*, *Sambucus canadensis*, *Triadica sebifera*, and *Viburnum nudum*. These woody taxa occupy the upper wooded fringe of Alderly marsh that experiences tidal flooding at the time of the new and full moon. While the aforementioned taxa are not true marsh associates they all can be found in fresh water swamps (Radford et al. 1968).

Among the three study sites, there is great variability with respect to species composition, dominance and diversity. The most saline marsh, Thousand Acre Rice Field, supports the fewest number of species, was least affected by Hurricane Hugo, and is little changed in species composition over 39 years. Airport marsh supports a large expanding population of *Phragmites*, a non-native species not observed here 39 years

ago. Alderly, the least saline marsh, contained the highest number of vascular taxa, 110. Alderly was most impacted by Hurricane Hugo resulting in a loss of species diversity when sampled immediately after Hurricane Hugo (Stalter and Baden 1994).

The two sites, Alderly and Airport, with 48 species in common, had the greatest floristic similarity (0.414, $P = 0.00001$). Alderly, the least saline site, and the Thousand Acre site, the most saline site, had the lowest floristic similarity (0.263, $P = 0.00019$, Table 4).

Species diversity was greatest at the least saline sites, Alderly and Airport, with 110 and 54 species, respectively. Twenty six species occur at all sites while 71 occur at only one site. Seven species including salt marsh associates *Borrchia frutescens*, *Distichlis spicata*, *Limonium carolinianum*, *Spartina alterniflora* and *S. patens* occur exclusively at Thousand Acre Rice Field, the most saline site. *Ipomoea sagittata*, a salt marsh fringe species was also found exclusively at Thousand Acre Rice Field. The genera *Borrchia*, *Distichlis*, *Ipomoea* and *Limonium* were found exclusively at Thousand Acre Rice Field. *Baccharis halimifolia* was the only woody species occurring at all sites. *Baccharis* has been listed as a salt marsh associate (Gleason & Cronquist 1991; Radford et al. 1968) yet it grows in profusion in North and South Carolina along I-95, miles from salt marshes. *Triadica sebifera*, an exotic, was observed in the upper intertidal Airport marsh. *Iva frutescens* and *Borrchia frutescens* were the only woody salt marsh species found exclusively at the most saline Thousand Acre Marsh.

Alderly

The most notable change in species dominance at Alderly is the increase in cover of *Phragmites australis*, a non-native species not present in 1968. *Taxodium distichum* was planted at this site in 1999 by Clemson University researchers; seedling survival ranged from 0 to 73% (Conner and Inabinette 2005). Several mature *T. distichum* in the Waccamaw River, adjacent to the Alderly marshes, have died; these individuals were alive in 1993 (Stalter & Baden 1994, Fig. 2).

Seedlings of *Taxodium distichum* from eight estuarine areas, from Mississippi to Virginia, were planted at Alderly in 1999 (Conner and Inabinette 2005). Only seedlings from Louisiana, Alabama and Florida survived the severe drought of 2001 when salinity values peaked at 18.5 parts per thousand (ppt) November 30, 2001 (Table 2). Seedlings from Louisiana were the most salt tolerant as 73% survived, while survival rates for Florida and Alabama seedlings were approximately 20% and 14% respectively. Experimental data from Conner and Inabinette (2005) suggest that there may be a wide range of salinity tolerance within populations of *Taxodium distichum*.

Periodic wet and dry periods plus infrequent hurricane surges have affected salinity at the brackish marshes during the 39 year study. The highest water salinity at Alderly occurred during Hurricane Hugo, when salt water in excess of 20 ppt penetrated up to 5 km inland (Blood et al. 1991; Gardner et al. 1991). "Normal" water salinity for the Alderly marshes is 1 ppt (Conner & Inabinette 2005). During a dry period from May 2002 to August 2002 salinity values at Alderly were above 8 ppt peaking at 14.6 ppt and 16.3 ppt in June and August, respectively. The high salinity values for Alderly followed the dry year of 2001, where salinity values ranged from 4 to 6 ppt from April to October; salinity values peaked at 18.5 ppt on November 30, 2001. Salinity values were generally 1 ppt or lower from 2003 to the spring of 2004.

Common species at Alderly are *Crinum americanum* and *Lilaeopsis chinensis* which grow in profusion around the edge of the marsh. *Crinum* is abundant around the boat dock today but nowhere else at Alderly. Other common vascular plants are *Alternanthera philoxeroides*, *Aster subulatus*, *Aster tenuifolias*, *Bidens laevis*, *Phragmites australis*, *Pontederia cordata*, *Sagittaria falcata*, *Scirpus americanus*, *S. robustus*, *S. validus*, *Spartina cynosuroides*, *Typha angustifolia* and *T. domingensis*.

Alderly may have been most affected by Hurricane Hugo's storm surge that brought salt water and salinity of up to 20 ppt to the marsh. In 1991, following Hurricane Hugo, 34 vascular plant species were identified. Forty seven species were reported in 1968 (Baden 1971). The latest survey 2002–2006, was conducted over a time of relatively high water salinity followed by a wet period when salinity values were less than 1 ppt. High vascular plant diversity in 2002–06 (86 species) compared to the studies of 1968 and 1991 may be a function of varying water salinity (Table 2). Eight woody taxa, those experiencing tidal flooding during



FIG. 2. *Taxodium distichum* at the Thousand Acre Rice Field.

new and full moon tides, reported earlier in the paper, are reported at Alderly for the first time. If the eight woody taxa were excluded from the list, the 78 vascular plant species at Alderly 2002–2006 would still be significantly higher than the 47 species reported at Alderly in 1968. A total of 105 species have been identified at Alderly during the 39 year study.

Thousand Acre Rice Field

Water salinity is highest in the Thousand Acre Rice Field (Table 2). Common species observed here were *Spartina cynosuroides*, *Cladium jamaicense*, *Juncus roemerianus*, *Scirpus robustus*, *Aster tenuifolius*, *A. subulatus*, *Lilaeopsis chinensis*, *Scirpus* spp. and *Typha* spp. The Thousand Acre Rice Field also supports salt marsh species, notably *Spartina alterniflora*, *S. patens*, *Distichlis spicata* and *Aster tenuifolius*. *Spartina alterniflora* borders the creeks and ditches that meander through this marsh and which experience flooding during every tide. Over half of the bald cypress, *Taxodium distichum*, at Thousand Acre Rice Field have died since the marsh was inundated by Hurricane Hugo's storm surge in 1989. The severe drought of 2001 and "high" salinity may also have contributed to the demise of *Taxodium* (Fig. 2).

Thousand Acre Rice Field supports the fewest number of vascular plant species. Twenty three taxa were reported in 1968, while 28 were identified here following Hurricane Hugo and 24 in 2006. The brackish plant species at the Thousand Acre Rice Field were little affected by Hurricane Hugo's storm surge. Disturbance by feeding pigs opening new habitats may account for the increase in number of plant species in 2006.

Prominent species in the Thousand Acre Rice Field were *Juncus roemerianus*, *Scirpus robustus*, *S. americanus*, *Spartina cynosuroides*, *Typha angustifolia* and *Rhynchospora miliacea*. Barry (1968) reported 12 vascular plant species at Thousand Acre Rice Field. The smaller number of species noted by Barry (1968) compared with 24 species collected during 2002–06 and 39 species over the 39 year study period, represents differences in sampling techniques. Barry sampled vegetation within small quadrats, placed along line transects; in the present study, the vascular flora in the whole marsh was sampled.

Barry (1980) noted the preference of *Juncus roemerianus* in less saline portions of salt marsh where salinity was less than 15 ppt. Where salinity exceeded 15 ppt, *Spartina alterniflora* replaced *J. roemerianus*.

Spartina alterniflora tolerated longer and deeper tidal flooding than *J. roemerianus*, and borders *J. roemerianus* along the Waccamaw River.

The vegetation noted by Barry (1968) in the Airport marsh and abandoned Thousand Acre Rice Field is similar to that observed today. Both Barry (1968) and Baden (1971) reported *Spartina cynosuroides* and *Scirpus robustus* growing in profusion on the western border of the old rice field along with the more numerous *Typha angustifolia*, *T. latifolia* with *Juncus* spp. Barry (1968) and Baden (1971) observed *Pontederia cordata*, *Sagittaria falcata*, *Peltandra virginica*, *Lilaeopsis chinensis* and *Hymenocallis crassifolia*. *Hymenocallis crassifolia* disappeared after Hurricane Hugo (Stalter and Baden 1994) and was not observed in 2002–2006.

Airport

The most significant change in vascular plant composition at the Airport Marsh is the increase of the non-native, *Phragmites australis*. *Phragmites* was first reported in a marsh bordering the west side of the Waccamaw River by Stalter (1975). Dikes and dredge spoils deposited on Baruch property in the 1970s may have created habitat favorable for the invasion of *Phragmites* (Stalter & Baden 1994).

The Airport Marsh experienced a decline in species composition over the 39 year study. Forty three species were identified in 1968–1969 (Baden 1971) while 30 were identified in 2002–2006. *Phragmites* has invaded Airport Marsh, outcompetes native species, and may be responsible for the decline in species diversity and absence of some vascular plant species reported in 1968. High salinity < 15 ppt during the drought of 2001 and 2002 may have killed salt intolerant taxa (Table 2).

Common taxa at Airport Marsh include *Spartina cynosuroides*, *Zizania aquatica*, *Juncus* spp., *Typha angustifolia*, *Cladium jamaicense*, *Scirpus robustus*, *Scirpus validus*, *Pontederia cordata*, *Aster subulatus*, *A. tenuifolius*, *Pluchea foetida* and *Lythrum lineare*. *Lilaeopsis chinensis* and *Ptilimnium capillaceum* are common at the edge of the marsh as are *Juncus biflorus*, *J. coriaceus*, *J. marginatus*, *J. nodosus*, *Hibiscus moscheutos* and *Samolus parviflorus*. Species diversity at Airport Marsh is greatest within the intertidal area.

APPENDIX

Species composition in three brackish marshes on the Belle W. Baruch Institute for Marine Biology and Coastal Research, Georgetown, South Carolina. Species observed in 1967–1971 are compared with those observed in 1987, 1991 and 2002–2006. Taxa in brackets are synonyms. Non-native taxa are scored with an asterisk (*) preceding the scientific name. Collection dates are omitted for woody taxa occurring at the upper marsh fringes flooded at the new and full moon.

POLYPODIOPHYTA

Blechnaceae

Woodwardia areolata (L.) Moore; occasional at marsh edge, Alderly, 2002–06

Osmundaceae

Osmunda cinnamomea L.; occasional at marsh edge, Alderly, 2002–06

Osmunda regalis (L.) var. *spectabilis* (Willd.) A. Gray; rare at marsh edge, 1968–06 Airport; occasional at Alderly, 2004–06

Thelypteridaceae

Thelypteris palustris Schott; occasional at marsh edge, Alderly, 2002–06

PINOPHYTA

Cupressaceae

Taxodium distichum (L.) Rich; occasional at 1000 Acre Rice field and Alderly, 1968–06; declining at both sites due to Hugo 1989 and drought of 2003.

MAGNOLIPHYTA—MAGNOLIOPSIDA

Amaranthaceae

**Alternanthera philoxeroides* (Mart.) Griseb.; common at Alderly 1991–06

Amaranthus cannabinus (L.) Sauer; occasional at marsh edge Airport and Alderly, 1968–06

Apiaceae

Eryngium aquaticum L.; rare at Airport 1991; occasional at Alderly 1991; rare at Alderly 2004

Hydrocotyle sp.; common at marsh border at all three marshes

Lilaeopsis chinensis (L.) Kuntze; common at marsh border at all three marshes

Ptilimnium capillaceum (Michx.) Raf.; common at marsh border at all three marshes

Sium suave Walt.; occasional at Airport 1991–06; occasional at Alderly 1968–06

Aquifoliaceae

Ilex cassine L. var. *cassine*; rare at marsh edge Alderly

Ilex opaca Ait.; occasional at marsh edge Alderly

Asteraceae

- Aster carolinianus* Walt.; occasional at Alderly, 2004–06
Aster subulatus Michx.; frequent at 1000 Acre Rice Field 1968 and 1991; frequent at marsh edge Airport 1968–06; occasional at Alderly 1968 and 1991
Aster tenuifolius L.; occasional at marsh edge 1000 Acre Rice Field 1968 and 1991; occasional at Airport 1968–06; occasional at Alderly 1968–06
Baccharis halimifolia Michx.; occasional at marsh edge, Alderly, 2004–06
Bidens laevis (L.) BSP.; occasional at marsh edge Airport and Alderly 1968 and 1991
Boltonia asteroides (L.) L' Hér.; rare at marsh edge Airport 1968
Borrchia frutescens (L.) DC.; occasional at edge of marsh, 1000 Acre Rice Field, 1968–06
Eupatorium album L.; occasional at Airport and Alderly immediately after Hurricane Hugo, 1991
Eupatorium coelestinum L.; occasional at marsh edge, Alderly, 2002–06
Eupatorium perfoliatum L.; occasional at marsh edge, Alderly, 2004–06
Iva frutescens L.; occasional, upper fringe of marsh at 1000 Acre Rice Field 1968–2006
Mikania scandens (L.) Willd.; occasional, upper fringe of marsh at 1000 Acre Rice Field and Alderly 1968–2006
Pluchea camphorata (L.) DC.; rare, 1000 Acre Rice Field, 1968
Pluchea foetida (L.) DC.; occasional at Airport, 1968–2006; occasional at Alderly 1968 and 1991
Solidago sempervirens L.; occasional at edge of marsh, 1000 Acre Rice Field 1991; Airport 1968 and 1991; Alderly 1968–06
Verbesina occidentalis (L.) Walt.; frequent at marsh border of Alderly, 1991–06

Betulaceae

- Alnus serrulata* (Ait.) Willd.; rare, marsh border of Alderly

Callitrichaceae

- Callitriche peploides* L.; occasional, marsh edge, Alderly, 2004–06

Caprifoliaceae

- Sambucus canadensis* L.; rare at edge of Alderly
Viburnum nudum L.; rare at edge of Alderly

Chenopodiaceae

- **Chenopodium album* L.; rare at edge of Airport and Alderly, 1968

Convolvulaceae

- Calystegia sepium* (L.) R. Br.; occasional, Alderly 2006
Dichondra carolinianus Michx.; frequent at marsh edge of Alderly, 2004–06
Ipomoea sagittata Poir.; occasional upper fringe of 1000 Acre Rice Field 1991–2006

Cuscutaceae

- Cuscuta pentagona* Engelm. [*Cuscuta campestris* Yunker]; occasional on assorted taxa, Alderly 1968 and 2004

Euphorbiaceae

- **Triadica sebifera* (L.) Small [*Sapium sebiferum* (L.) Roxb.]; occasional on marsh fringe of Airport, 2004–06

Fabaceae

- Chamaecrista fasciculata* (Michx.) Greene [*Cassia fasciculata* Michx.]; occasional upper marsh fringe of Airport and Alderly, 1968

Gentianaceae

- Sabatia calycina* (Lam.) Heller; rare, 1000 Acre Rice Field 1968; Alderly 1968 and 1991
Sabatia stellaris Pursh.; frequent 1000 Acre Rice Field and Alderly 1968–06; occasional Airport 1968

Grossulariaceae

- Itea virginica* L.; rare, upper marsh fringe of Alderly

Lamiaceae

- Lycopus virginicus* L.; occasional at marsh edge, Alderly, 2004–06
Scutellaria integrifolia L.; rare, Alderly, 2004–06
Stachys floridana Shuttlew. ex Benth.; abundant, Alderly 2006

Lythraceae

- Lythrum lineare* L.; abundant at all marshes 1968–06

Malvaceae

- Hibiscus moscheutos* L.; occasional at edge of marsh, Airport and Alderly 1968–06

Nymphaeaceae

- Nuphar lutea* (L.) Sm. ssp. *sagittifolia* (Walt.) E.O. Beal; occasional at small ponds at Alderly, 1968–06
Nymphaea odorata Ait.; rare by culvert, Alderly 2004–06

Nyssaceae

- Nyssa biflora* Walt. [*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.]; occasional at marsh fringe, Alderly

Plumbaginaceae

- Limonium carolinianum* (Walt.) Britt.; rare, 1000 Acre Rice Field 1968 and 2004

Polygonaceae

- Polygonum hydropiperoides* Michx.; frequent at edge of marsh 1000 Acre Rice Field, 1991–06 and Airport 1968 and 2006, and Alderly, 1968–06
Polygonum sagittatum L.; rare at Alderly, 2004–06
Rumex verticillatus L.; rare at Airport, 1968; occasional at Alderly 1968–06

Potamogetonaceae

- Potamogeton diversifolius* Raf.; rare, Alderly at pool near culvert 2004–06

Primulaceae

- Samolus valerandi* L. ssp. *parviflorus* (Raf.) Hulten [*S. parviflorus* Raf.]; frequent at edge of marsh at all sites 1968–2006; occasional upper marsh fringe of Alderly, 1968–06

Rosaceae

- Rosa laevigata* Michx.; rare, upper marsh fringe of Alderly
Rosa palustris Marsh.; occasional upper marsh fringe of Alderly

Rubiaceae

Cephalanthus occidentalis L.; rare, upper fringe of Airport 1968–06; occasional, upper marsh fringe of Alderly 1968–06

Galium obtusum Bigel.; frequent, Alderly 2006

Salicaceae

Salix caroliniana Michx.; occasional, upper marsh fringe of Alderly

Saururaceae

Saururus cernuus L.; frequent at Alderly 1968–06

Scrophulariaceae

Bacopa caroliniana (Walt.) B.L. Robins.; occasional at Alderly, 2004–06

Bacopa monnieri (L.) Pennell; rare at edge of marsh, Airport 1968

Urticaceae

Boehmeria cylindrica (L.) Swartz.; occasional at Alderly, 1991–06

Verbenaceae

Phyla lanceolata (Michx.) Geene; occasional at marsh edge, 1000 Acre Rice Field 1968–06; abundant at marsh edge, Airport 1968–06

**Verbena brasiliensis* Vell.; rare, Alderly, 2006

MAGNOLIOPHYTA—LILIOPSIDA**Alismataceae**

Sagittaria lancifolia L. [*S. falcata* Pursh]; occasional at Airport, 1991–06; abundant at Alderly 1968–06

Araceae

Orontium aquaticum L.; rare at Alderly, 1968–06

Peltandra virginica (L.) Schott; frequent at Airport and Alderly 1968–06

Commelinaceae

**Murdannia keisak* (Hassk.) Hand.-Maz. [*Aneilema keisak* Hassk.]; abundant at Alderly, 2004–06

Cyperaceae

Cladium jamaicense Crantz; abundant at all marshes 1968–06

Carex alata Torr.; occasional at marsh edge Airport and Alderly 1968–06

Carex atlantica L.H. Bailey; occasional, Alderly 2006

Carex lurida Wahlenb.; occasional, Alderly 2006

Carex stipata Willd.; rare, Alderly 2006

Cyperus drummondii; rare at Alderly 2004

Cyperus refractus Engelm. ex Boeckl.; occasional at Alderly 2004–06

Cyperus strigosus L.; occasional at edge of marsh Alderly 2004–06

Eleocharis engelmannii Steud.; occasional at all 3 marshes, 1968; and at 1000 Acre Rice Field and Alderly, 1991

Eleocharis flavescens (Poir.) Urb.; occasional, Alderly, 2006

Eleocharis quadrangulata (Michx.) R. & S.; rare at Airport and Alderly 1968; rare at Alderly 2004–06

Fimbristylis thermalis S. Wats. [*Fimbristylis spadicea* auct. non

(L.) Vahl]; frequent at 1000 Acre Rice Field and Airport 1968–06; rare at Alderly 68

Rhynchospora colorata (L.) H. Pfeiffer [*Dichromena colorata* (L.) Hitchc.]; occasional at marsh edge at Alderly 1968–06

Rhynchospora miliacea (Lam.) Gray; rare at 1000 Acre Rice Field, 2004–06; occasional to locally abundant at Alderly, 1968–06

Scirpus cyperinus (L.) Kunth; occasional at Alderly 1968–06

Scirpus pungens Vahl. [*S. americanus* Pers.]; abundant at 1000 Acre Rice Field and Airport 1968–06; occasional at Alderly 1968–91.

Scirpus tabernaemontani K.C. Gmel. [*Scirpus validus* Vahl]; abundant at 1000 Acre Rice Field 1968–2006 and at Alderly 1968–91.

Iridaceae

Iris virginica L.; frequent at Alderly 1968–06

Juncaceae

Juncus acuminatus Michx.; rare at Alderly 1968

Juncus biflorus Ell.; occasional at 1000 Acre Rice Field 1968 and 1991; rare at Airport and Alderly, 1968

Juncus coriaceous Mackenzie; occasional at marsh edge, 1000 Acre Rice Field 1968 and 1991; occasional at Airport and Alderly 1968–06

Juncus dichotomus Ell.; occasional at Alderly 2006

Juncus effusus L.; occasional at Alderly 2006

Juncus marginatus Rostk.; occasional at Airport 1968–06

Juncus nodosus L.; occasional at Airport 1991 and 2004

Juncus roemerianus Scheele.; abundant at 1000 Acre Rice Field 1968–06 and Alderly at the border of the Waccamaw River 1968–06; occasional at Airport 1968

Liliaceae

Crinum americanum L.; abundant in vicinity of Taylor boat landing, Alderly at the edge of the marsh 1968–06

Hymenocallis floridana (Raf.) Morton [*Hymenocallis crassifolia* Herbert]; occasional at Alderly 1968, extirpated by Hurricane Hugo 1989

Poaceae

**Arundo donax* L.; rare at marsh edge 1000 Acre Rice Field 1968 and 1991; rare at marsh edge Airport 1991; occasional at Alderly near Waccamaw River 1968–06

Chasmanthium latifolium (Michx.) Yates [*Uniola latifolia* Michx.]; occasional at edge of marsh, Alderly, 1968–1991

Chasmanthium laxum (L.) Yates [*Uniola laxa* (L.) B.S.P.]; occasional at edge of marsh, Alderly 1968–06

Cinna arundinacea L.; frequent at marsh border Airport and Alderly 1968–06

Distichlis spicata (L.) Greene; abundant at 1000 Acre Rice Field 1968–06

**Echinochloa crus-galli* (L.) P. Beauv.; occasional at marsh border Airport 1968–06; occasional at marsh border Alderly 1968–06

Erianthus giganteus (Walt.) Muhl.; frequent at marsh edge Alderly 1968–06

Leersia oryzoides (L.) Sw.; abundant at Alderly 2004–06

Panicum virgatum L.; frequent at marsh border 1000 Acre Rice

Field 1991 and 2006; frequent at marsh border Airport and Alderly 1968–06
Panicum sp.; occasional at marsh border Alderly 2004–06
Paspalum distichum L.; occasional at marsh border, Airport 1968 and 2004–06
 **Phragmites australis* (Cav.) Trin.; abundant at all marshes 2004–06; see text for additional information
Setaria magna Griseb.; occasional at marsh border, all marshes 1968
Spartina alterniflora Loisel; abundant along ditches, 1000 Acre Rice Field 1968–06
Spartina cynosuroides (L.) Roth; abundant at all marshes 1968–06
Spartina patens (Ait.) Muhl.; abundant at 1000 Acre Rice Field 1968–06

Tripsacum dactyloides (L.) L.; rare at 1000 Acre Rice Field edge 2004–06; occasional at marsh edge Alderly 1968–06
Zizania aquatica L.; occasional at 1000 Acre Rice Field 2004; abundant at Airport and Alderly 1968–06
Zizaniopsis miliacea (Michx.) Doell & Aschers.; frequent at Airport and Alderly 1968–06

Pontederiaceae

Pontederia cordata L.; rare at Alderly 2004–06

Typhaceae

Typha angustifolia L.; frequent at all marshes 1968–06
Typha domingensis Pers.; frequent at 1000 Acre Rice Field 1991–06, occasional at Alderly 1991–06
Typha latifolia L.; abundant at 1000 Acre Rice Field 1968–06; occasional at Alderly 1968–06

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